Remote sensing: satellite radar for ocean winds

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Remote sensing: satellite radar for ocean winds

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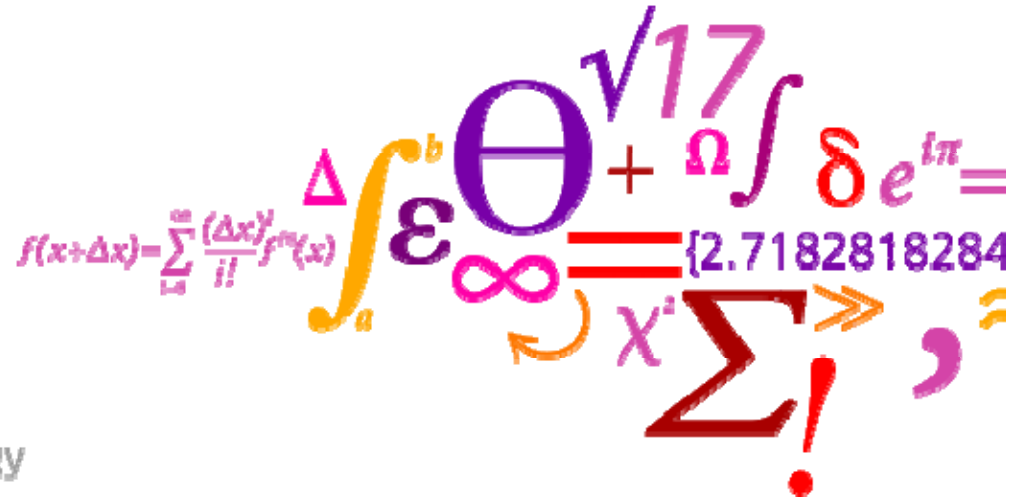
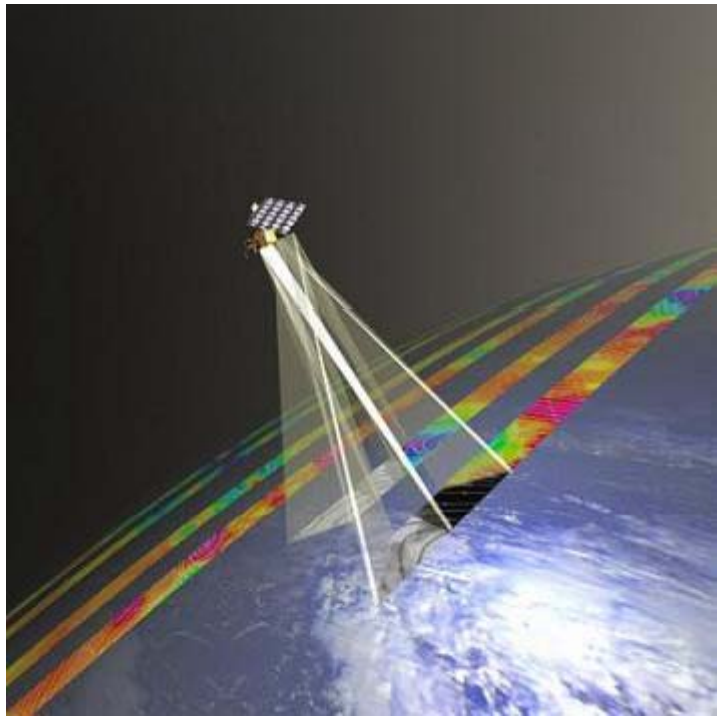
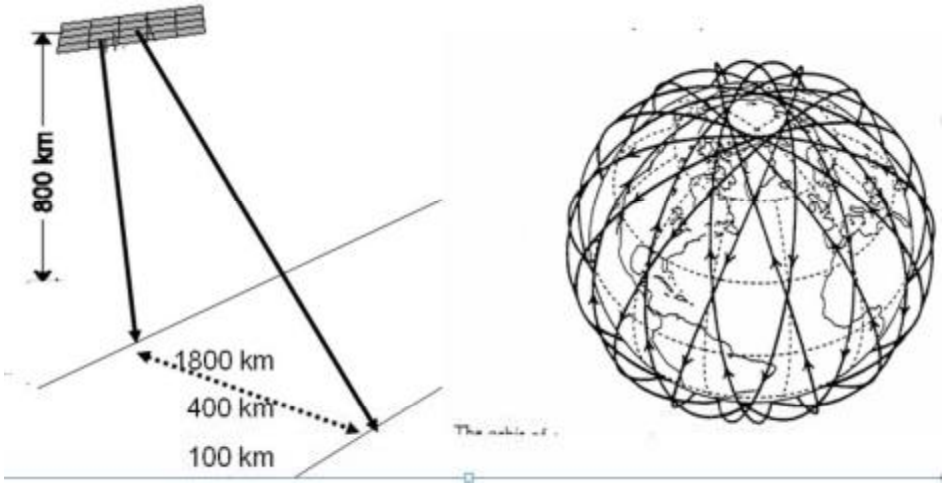


Risø DTU
National Laboratory for Sustainable Energy

Selected radar satellites (QuikSCAT, Envisat, ASCAT)

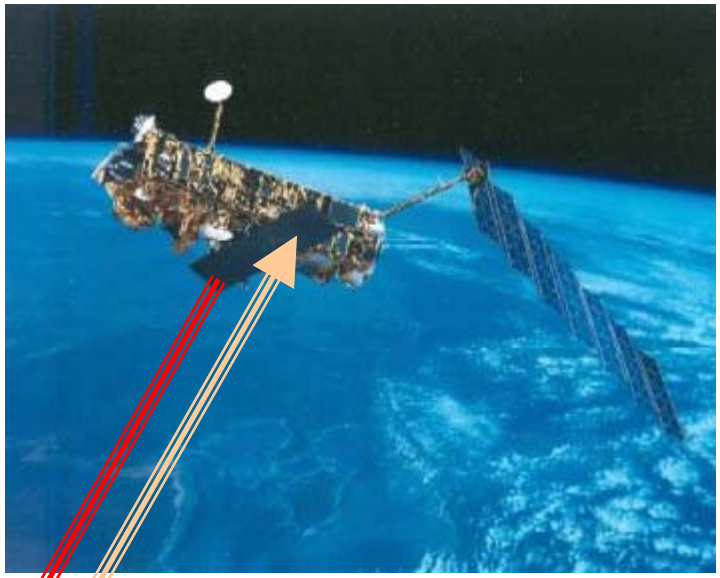


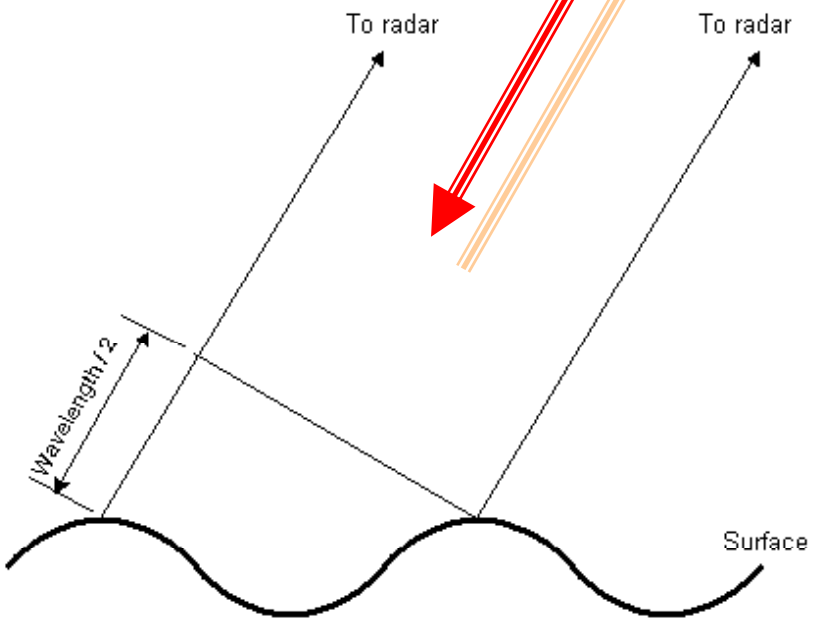


Physics

Ocean surface roughens by wind interaction: Capillary and short gravity waves are generated.

More wind causes more steep waves causes higher backscatter.





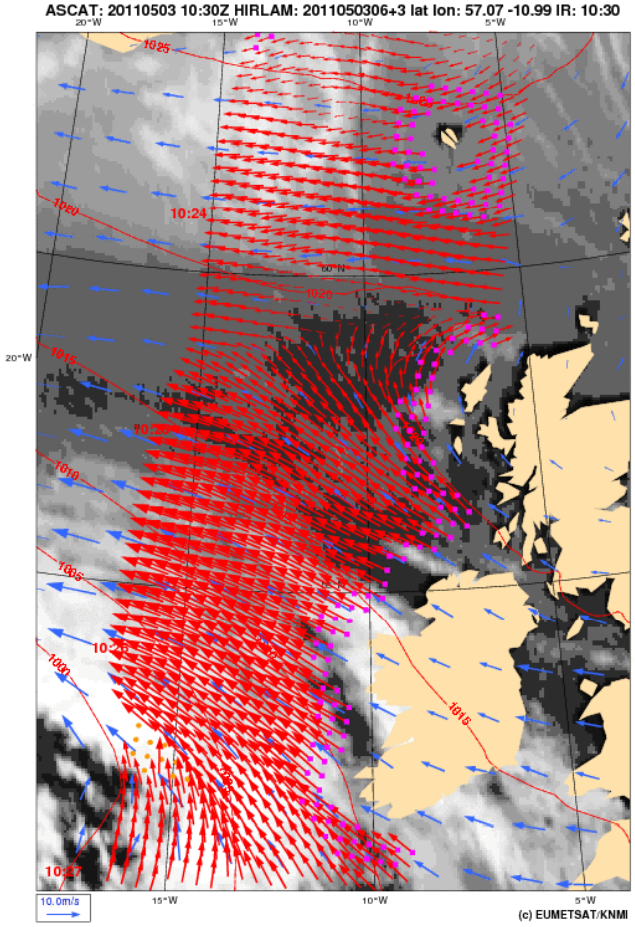
Technical

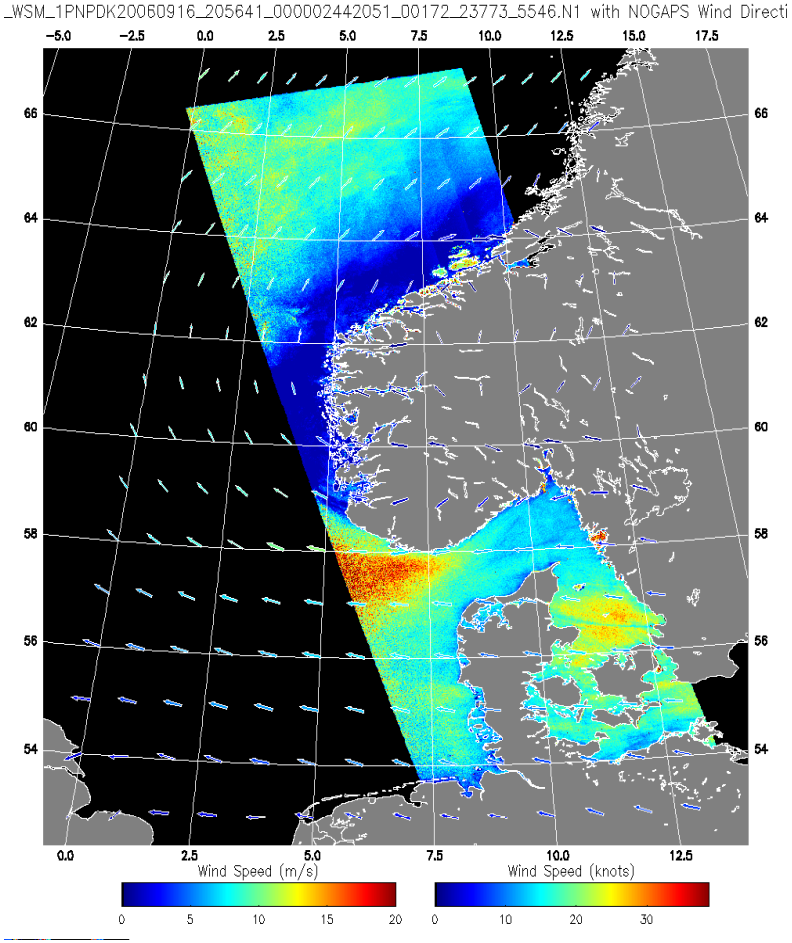
Ocean wind speed (U) is calculated through emperical geophysical model function relating the observed normalized radar cross section (NRCS) with incidence angle (γ) and wind direction (θ).

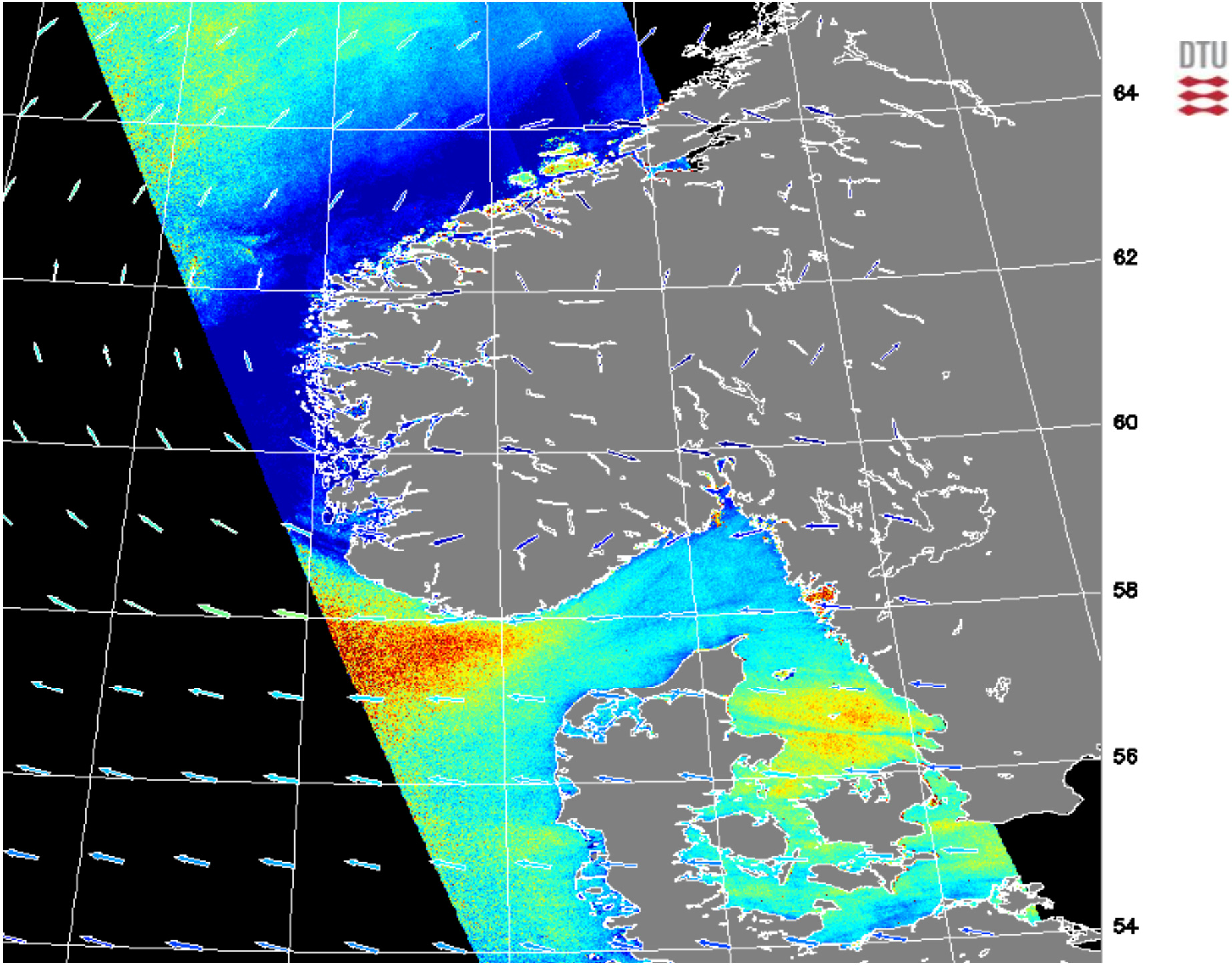
$U=f(NRCS, \theta, \gamma)$

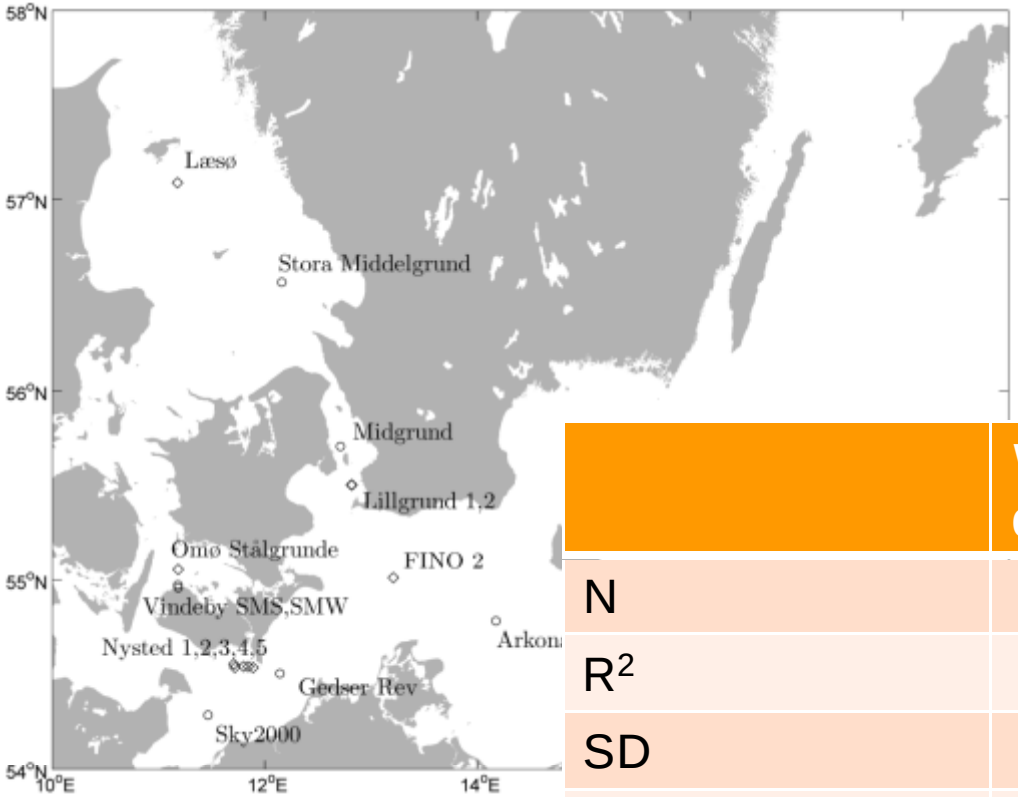
Accuracy

Wind speed < 2 m/s rms error, Wind direction < 20° rms error



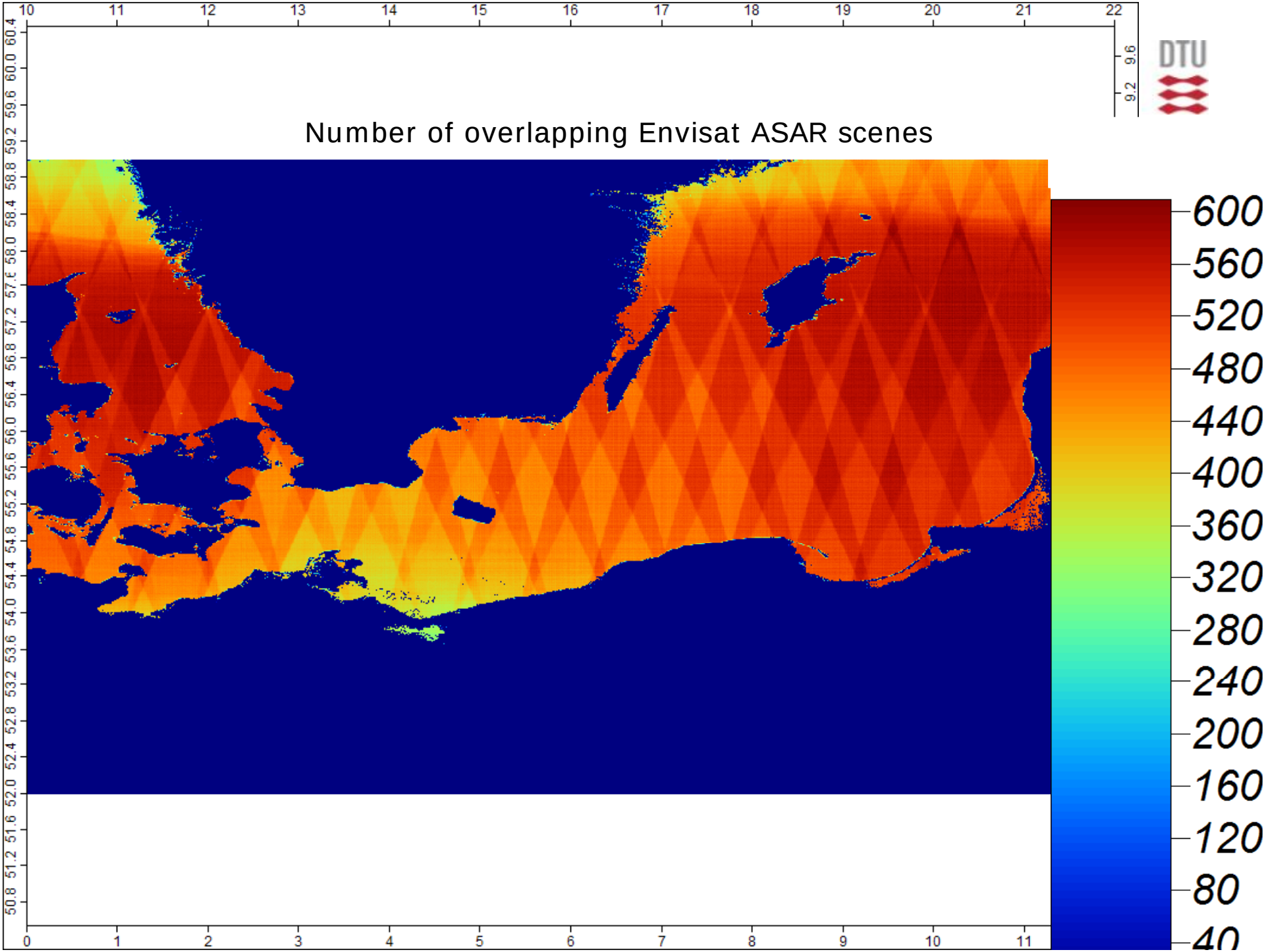


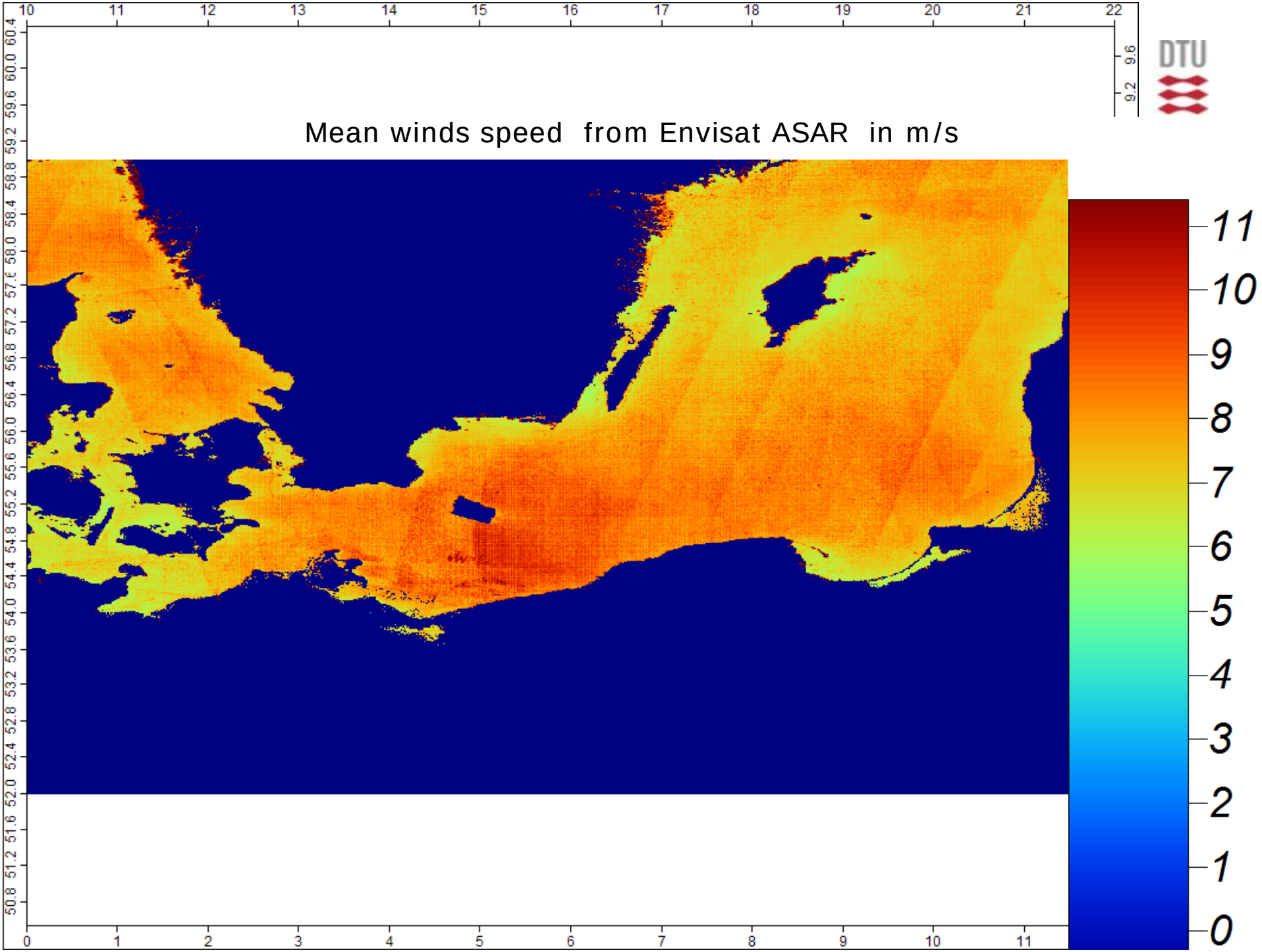

64
62
60
58
56
54



	Wind direction	Wind speed
N	927	875
R^2	0.950	0.783
SD	20.11°	1.88 ms^{-1}
RMS	6.29°	1.27 ms^{-1}
Bias	7.75°	-0.25 ms^{-1}
Slope	0.99	0.96

Charlotte B. Hasager, Merete Badger, Alfredo Peña, Xiaoli G. Larsén and Ferhat Bingöl
Article: SAR-Based Wind Resource Statistics in the Baltic Sea
Remote Sens. **2011**, *3*(1), 117-144; doi:10.3390/rs3010117


Number of overlapping Envisat ASAR scenes
DTU
10 11 12 13 14 15 16 17 18 19 20 21 22
9.2 9.6
60.4 60.0 59.6 59.2 58.8 58.4 58.0 57.6 57.2 56.8 56.4 56.0 55.6 55.2 54.8 54.4 54.0 53.6 53.2 52.8 52.4 52.0 51.6 51.2 50.8
0 1 2 3 4 5 6 7 8 9 10 11
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40


Mean winds speed from Envisat ASAR in m/s
DTU
10 11 12 13 14 15 16 17 18 19 20 21 22
9.2 9.6
60.4 60.0 59.6 59.2 58.8 58.4 58.0 57.6 57.2 56.8 56.4 56.0 55.6 55.2 54.8 54.4 54.0 53.6 53.2 52.8 52.4 52.0 51.6 51.2 50.8
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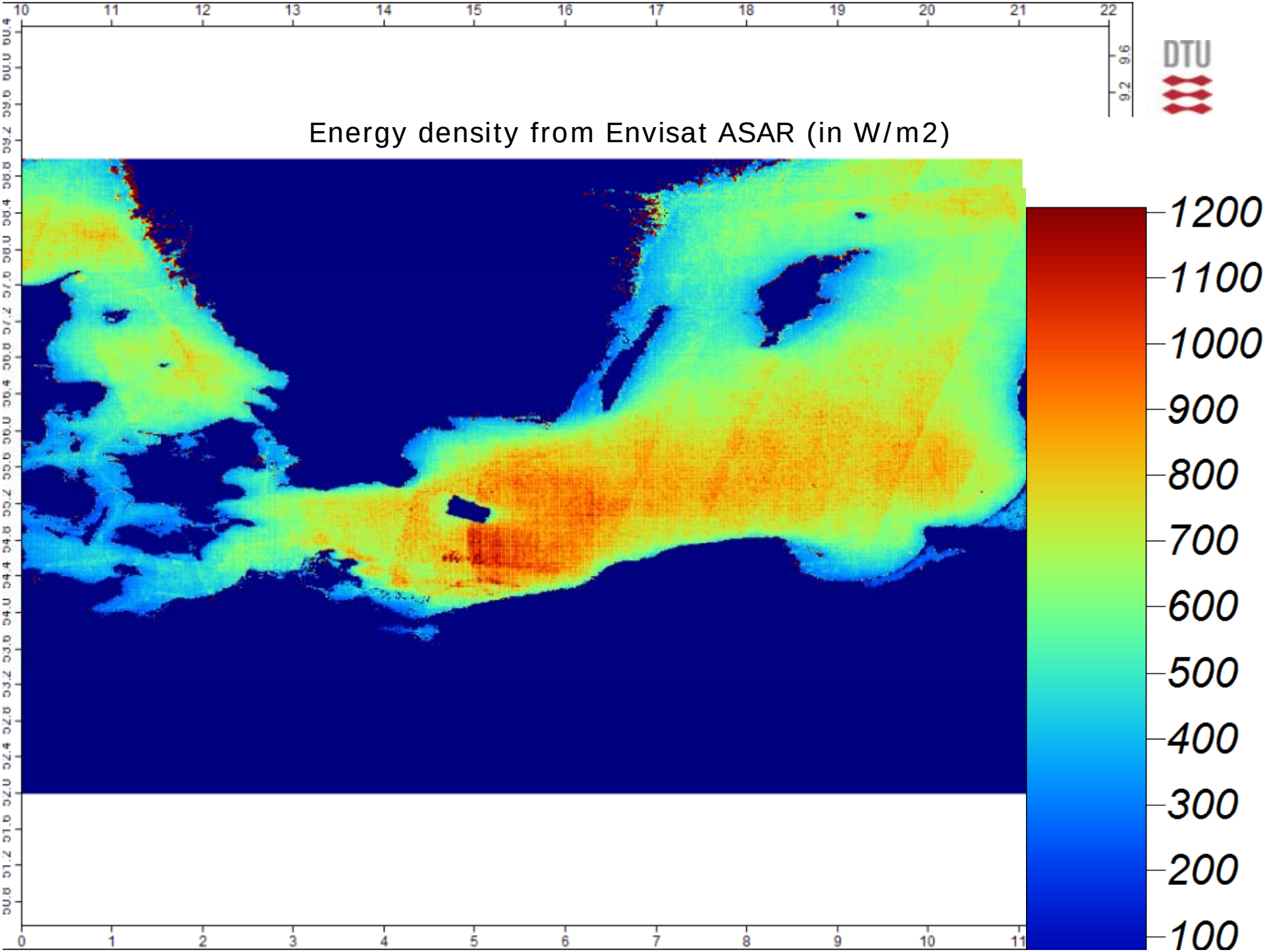
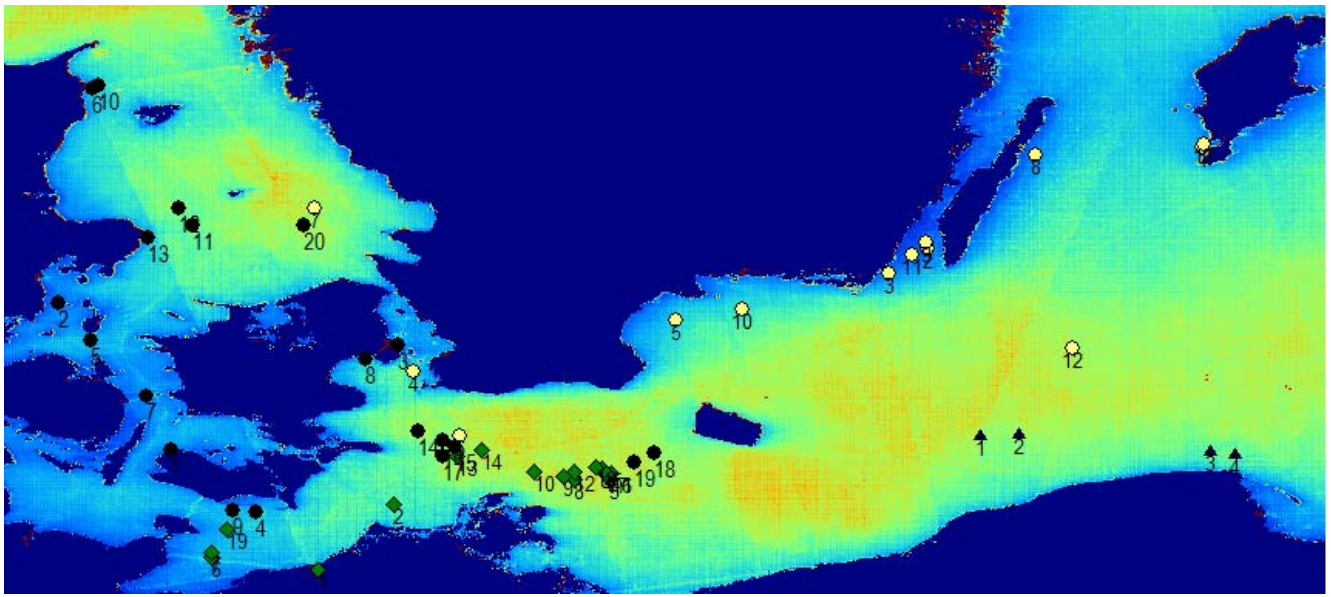
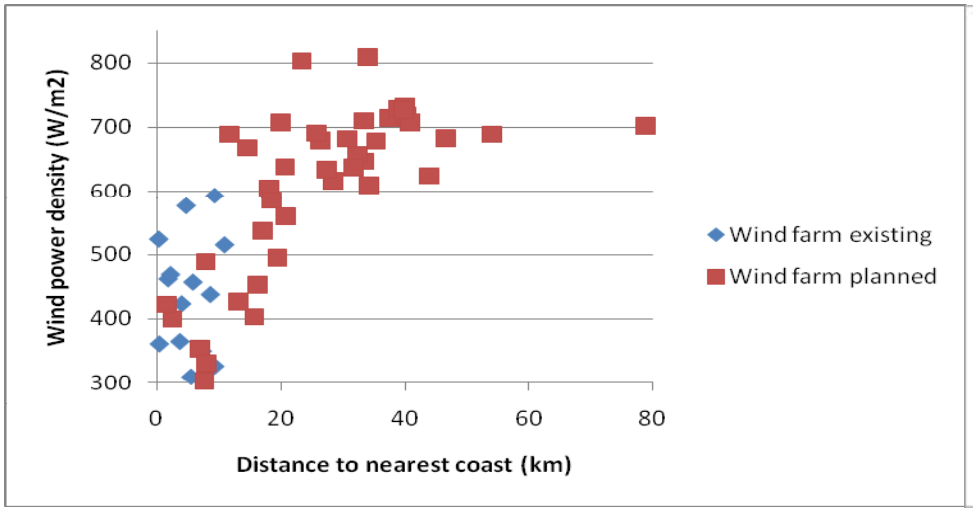
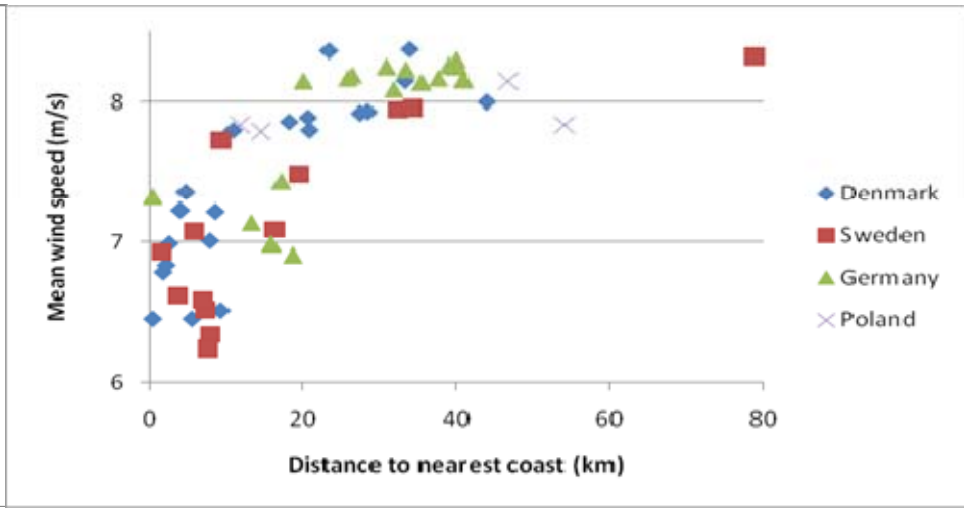
11 10 9 8 7 6 5 4 3 2 1 0


Energy density from Envisat ASAR (in W/m2)
1200
1100
1000
900
800
700
600
500
400
300
200
100

Baltic Sea existing and planned offshore wind farms







North Sea study

- Høvsøre (coastal)
- Horns Rev (offshore)
- FINO-1 (offshore)

Badger, M., Badger, J., Nielsen, M., Hasager, C.B., Peña, P. (2010)

Wind class sampling of satellite SAR imagery for offshore wind resource mapping.

J. of Applied Meteorology and Climatology, 49,12, 2474-2491, doi: 10.1175/2010JAMC2523.1

North Sea summary

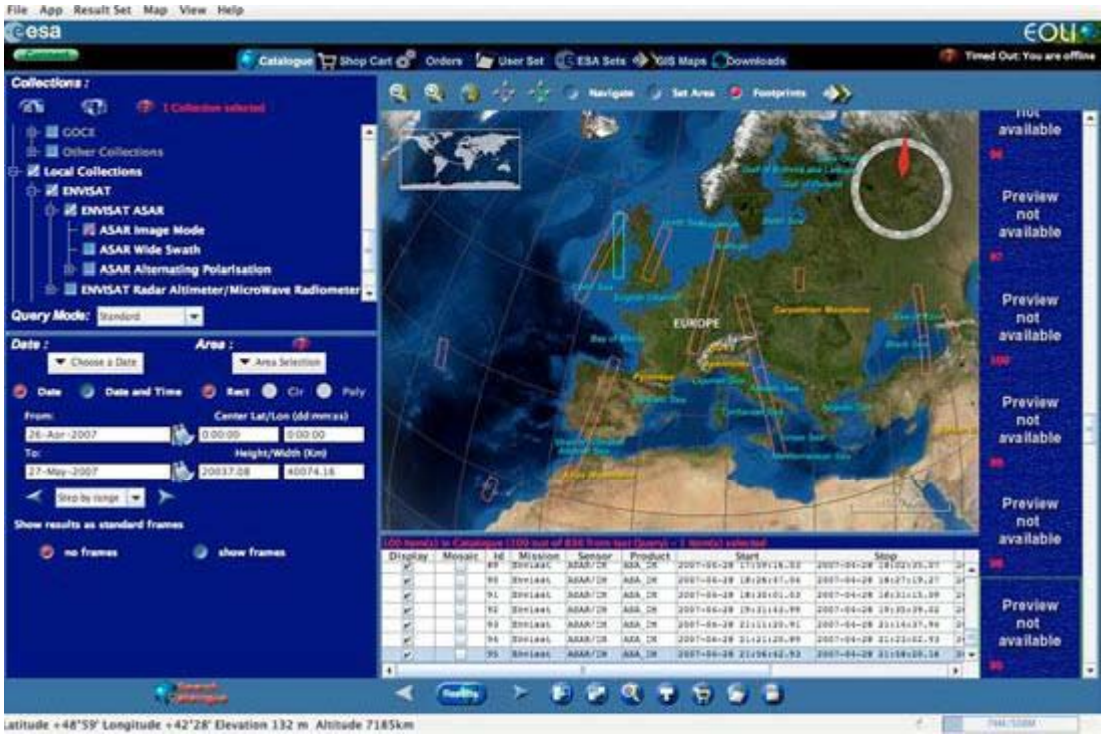
	Mean error	Mean absolute error
U (%)	-1.8	2.2
A (%)	-2.0	2.4
k (%)	-3.7	3.7
E (%)	-2.3	3.5

- Good overall agreement with mast observations on the wind resource
  - *within ±5% for the mean wind speed and Weibull A*
  - *within ±7% for the power density and Weibull k*

- The accuracy on wind resource assessment from mesoscale modeling is typically 10-15%

SAR global view

ESA archive, use EOLI



Risø DTU has experience in

- North Sea
- Baltic Sea
- Irish Sea
- Japan
- China
- India
- United Arab Emirates
- Mediterranean
- Portugal
- Iceland
- Egypt
- Galathea 3 expedition

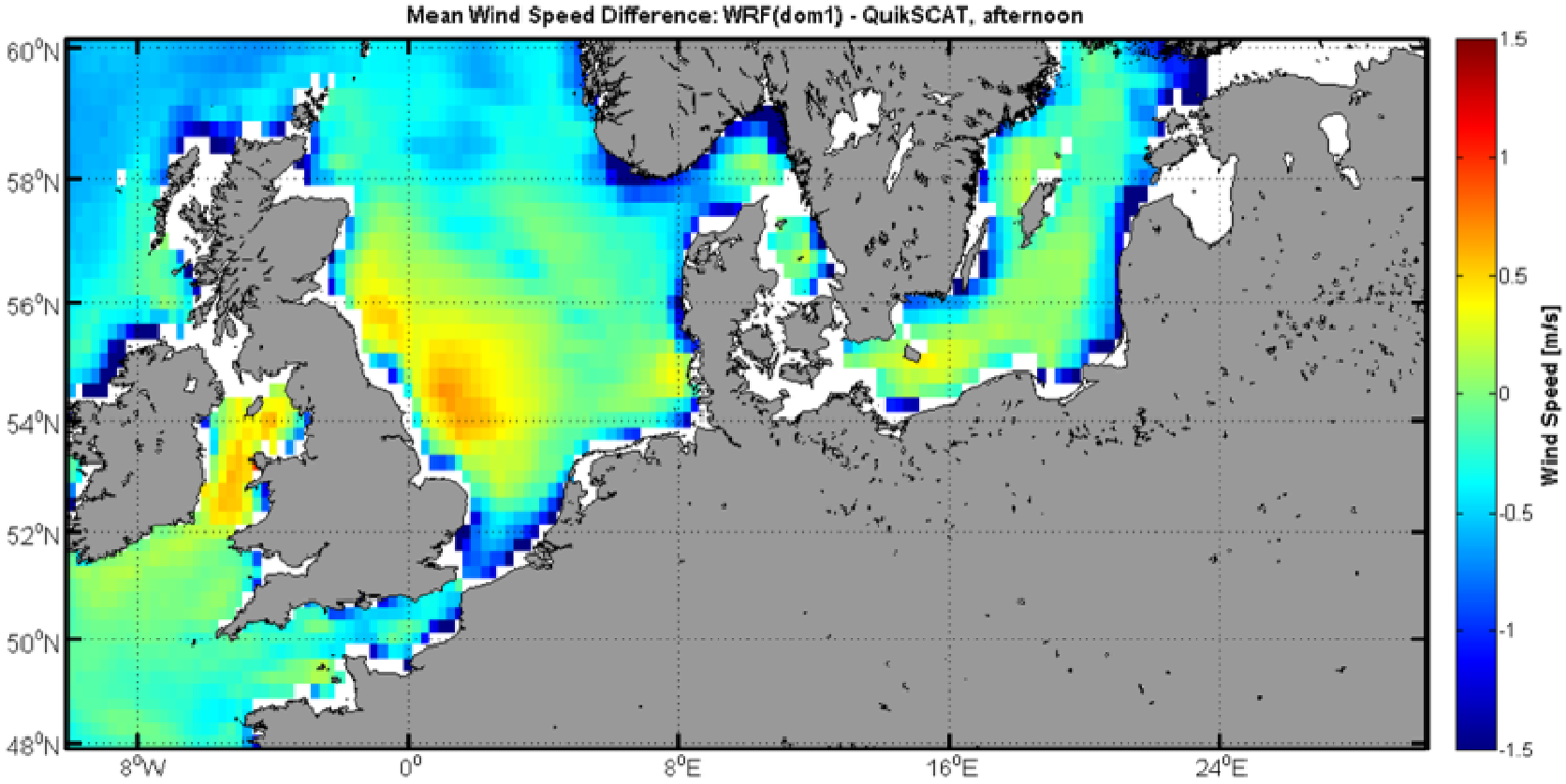
among more

Others include

- Canada
- USA
- Black Sea
- South Korea
- Taiwan

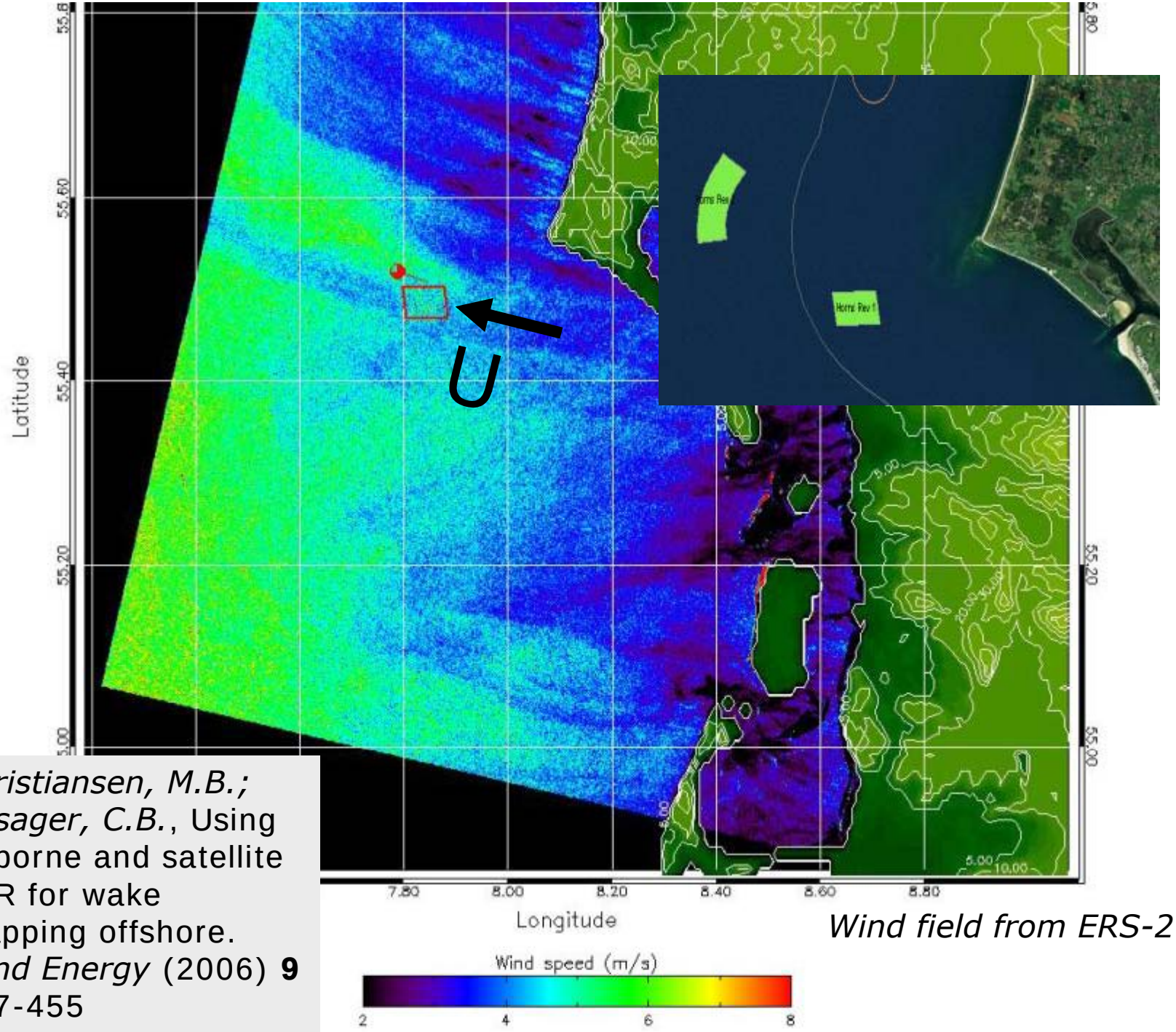
among more

Northern Seas WRF minus QuikSCAT, 10 yr



North Sea German Bight plans

Source http://www.4coffshore.com/offshorewind/



Wind field from ERS-2 SAR

Christiansen, M.B.; Hasager, C.B., Using airborne and satellite SAR for wake mapping offshore. *Wind Energy* (2006) **9** 437-455

Conclusions

Satellite remote sensing provides ocean winds

•Long archives 1987 to present (SSM/I, ERS, QuikSCAT, ASCAT, etc.)

•Twice daily global coverage (QuikSCAT for 10 yr, 1999-2009)

•High spatial resolution (ERS SAR, Envisat ASAR, Radarsat, etc.)

•Accuracy relevant for pre-feasibility

•Independent data source for evaluation of atmospheric models

OFFSHORE WINDS: state-of-the-art COMBINING satellite and modelling

Acknowledgements

Satellite data from:
Envisat ASAR from ESA Cat. 1 project 3644 and ESA-CSA SOAR project 6773
QuikSCAT from Remote Sensing Systems
ASCAT from EUMETSAT
The Johns Hopkins University, Applied Physics Laboratory, USA is thanked for providing and supporting the APL/NOAA SAR Wind Retrieval System (ANSWRS).

Other data from:
WRF model results from Andrea Hahmann
Comparison to WRF from Ioanna Karagali
Envisat ASAR analysis from Merete Badger and Ferhat Bingöl
Comparison to met data Alfredo Peña
Photo of wind farm wake from Vattenfall
Met-data from DONG Energy, Vattenfall and BMU.
Offshore wind farm map from http://www.4coffshore.com/

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